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**April 20, 2005**

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**APPLICATION NUMBER:** ***60/619,931***
**FILING DATE:** ***October 20, 2004***

CA/05/403

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# PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No.

**INVENTOR(S)**

| Given Name (first and middle [if any]) | Family Name or Surname | Residence (City and either State or Foreign Country) |
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| Barrie | KIRK | Ottawa, Ontario, CANADA |
| Keith | FAGAN | Ottawa, Ontario, CANADA |

*Additional inventors are being named on the* ________ *separately numbered sheets attached hereto*

**TITLE OF THE INVENTION (500 characters max):**

SYSTEM FOR USING CELL-PHONES AS TRAFFIC PROBES

*Direct all correspondence to:* **CORRESPONDENCE ADDRESS**

☑ The address corresponding to Customer Number: 26123

**OR**

☐ Firm or Individual Name

| Address | | |
|---|---|---|
| City | State | Zip |
| Country | Telephone | Fax |

**ENCLOSED APPLICATION PARTS** ***(check all that apply)***

☑ Specification *Number of Pages* 22

☑ Drawing(s) *Number of Sheets* 6

☐ Application Data Sheet. See 37 CFR 1.76

☐ CD(s), Number of CDs —

☐ Other (specify)

**METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT**

☑ Applicant claims small entity status. See 37 CFR 1.27.

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SIGNATURE [signature]

Date October 20, 2004

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Docket Number: PAT 2253AP-2

***USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT***

22713 U.S. PTO
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# FEE TRANSMITTAL for FY 2005

*Effective 10/01/2004. Patent fees are subject to annual revision.*

☑ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 80.00

| Complete if Known | |
|---|---|
| Application Number | |
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| First Named Inventor | Barrie KIRK et al. |
| Examiner Name | |
| Art Unit | |
| Attorney Docket No. | PAT 2253AP-2 |

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## FEE CALCULATION

### 1. BASIC FILING FEE

| Large Entity Fee Code | Fee ($) | Small Entity Fee Code | Fee ($) | Fee Description | Fee Paid |
|---|---|---|---|---|---|
| 1001 | 790 | 2001 | 395 | Utility filing fee | |
| 1002 | 350 | 2002 | 175 | Design filing fee | |
| 1003 | 550 | 2003 | 275 | Plant filing fee | |
| 1004 | 790 | 2004 | 395 | Reissue filing fee | |
| 1005 | 160 | 2005 | 80 | Provisional filing fee | 80.00 |

SUBTOTAL (1) ($) 80.00

### 2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

| | | Extra Claims | Fee from below | Fee Paid |
|---|---|---|---|---|
| Total Claims | -20** = | | X | = |
| Independent Claims | - 3** = | | X | = |
| Multiple Dependent | | | | = |

| Large Entity Fee Code | Fee ($) | Small Entity Fee Code | Fee ($) | Fee Description |
|---|---|---|---|---|
| 1202 | 18 | 2202 | 9 | Claims in excess of 20 |
| 1201 | 88 | 2201 | 44 | Independent claims in excess of 3 |
| 1203 | 300 | 2203 | 150 | Multiple dependent claim, if not paid |
| 1204 | 88 | 2204 | 44 | ** Reissue independent claims over original patent |
| 1205 | 18 | 2205 | 9 | ** Reissue claims in excess of 20 and over original patent |

SUBTOTAL (2) ($)

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## FEE CALCULATION (continued)

### 3. ADDITIONAL FEES

| Large Entity Fee Code | Fee ($) | Small Entity Fee Code | Fee ($) | Fee Description | Fee Paid |
|---|---|---|---|---|---|
| 1051 | 130 | 2051 | 65 | Surcharge - late filing fee or oath | |
| 1052 | 50 | 2052 | 25 | Surcharge - late provisional filing fee or cover sheet | |
| 1053 | 130 | 1053 | 130 | Non-English specification | |
| 1812 | 2,520 | 1812 | 2,520 | For filing a request for *ex parte* reexamination | |
| 1804 | 920* | 1804 | 920* | Requesting publication of SIR prior to Examiner action | |
| 1805 | 1,840* | 1805 | 1,840* | Requesting publication of SIR after Examiner action | |
| 1251 | 110 | 2251 | 55 | Extension for reply within first month | |
| 1252 | 430 | 2252 | 215 | Extension for reply within second month | |
| 1253 | 980 | 2253 | 490 | Extension for reply within third month | |
| 1254 | 1,530 | 2254 | 765 | Extension for reply within fourth month | |
| 1255 | 2,080 | 2255 | 1,040 | Extension for reply within fifth month | |
| 1401 | 340 | 2401 | 170 | Notice of Appeal | |
| 1402 | 340 | 2402 | 170 | Filing a brief in support of an appeal | |
| 1403 | 300 | 2403 | 150 | Request for oral hearing | |
| 1451 | 1,510 | 1451 | 1,510 | Petition to institute a public use proceeding | |
| 1452 | 110 | 2452 | 55 | Petition to revive - unavoidable | |
| 1453 | 1,370 | 2453 | 685 | Petition to revive - unintentional | |
| 1501 | 1,370 | 2501 | 685 | Utility issue fee (or reissue) | |
| 1502 | 490 | 2502 | 245 | Design issue fee | |
| 1503 | 660 | 2503 | 330 | Plant issue fee | |
| 1460 | 130 | 1460 | 130 | Petitions to the Commissioner | |
| 1807 | 50 | 1807 | 50 | Processing fee under 37 CFR 1.17(q) | |
| 1806 | 180 | 1806 | 180 | Submission of Information Disclosure Stmt | |
| 8021 | 40 | 8021 | 40 | Recording each patent assignment per property (times number of properties) | |
| 1809 | 790 | 2809 | 395 | Filing a submission after final rejection (37 CFR 1:129(a)) | |
| 1810 | 790 | 2810 | 395 | For each additional invention to be examined (37 CFR 1.129(b)) | |
| 1801 | 790 | 2801 | 395 | Request for Continued Examination (RCE) | |
| 1802 | 900 | 1802 | 900 | Request for expedited examination of a design application | |

Other fee (specify) ____

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SUBTOTAL (3) ($)

## SUBMITTED BY

(Complete (*if applicable*))

| Name (*Print/Type*) | Dilip C. Andrade | Registration No. (*Attorney/Agent*) | 53,942 | Telephone | 613-237-5160 |
|---|---|---|---|---|---|
| Signature | [signature] | | | Date | October 20, 2004 |

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# SYSTEM FOR USING CELL-PHONES AS TRAFFIC PROBES

## FIELD OF THE INVENTION

**[0001]** The present invention relates generally to traffic information. More particularly, the present invention relates to the use of assisted Global Positioning System (GPS) enabled cellular phones as traffic probes in a traffic management and control system.

## BACKGROUND OF THE INVENTION

**[0002]** Many drivers on current road infrastructure wish to have advance notification of impairments to their movement, thereby allowing them to choose a route that will be more efficient at a specific time of day. These users are interested in the current speed of traffic along major routes, any congestion due to traffic volume, accidents or planned outages that might impair progress, weather conditions etc.

**[0003]** Traffic congestion in major cities is generally increasing, and there is strong interest, on the part of drivers, in receiving more detailed real-time traffic information. To satisfy these requirements, traffic information must be complete, accurate and timely. In addition, the information must be presented in a fashion that is readily available and can be safely delivered.

**[0004]** Automated traffic monitoring systems are known in the art, and are taught in references such as Canadian Patent Application No. 2,235,184 and 2,257,438 both of which are incorporated herein by reference.

**[0005]** Currently traffic management relies upon information collected from infrastructure based sensors such as wire loops under highways that detect the movement of vehicles above them, cameras used to illustrate traffic flow, and transponders such as those used on toll roads. These components require an infrastructure that can be difficult to install after the installation of the roadway. The lack of such sensors results in an insufficient amount information to be useable for a commercial service. Additionally, substantial expansion of government-owned traffic sensor networks is not feasible in many jurisdictions due to the resources required to significantly expand road sensor networks.

**[0006]** Globis Data Inc. of Kanata Ontario Canada provides DRIVES™ services that are categorized as Traveller Information Services. Traveller Information Services consists of

user services designed to use advanced systems and technologies to manage information to help drivers decide when to drive and the route to drive, as well as opportunities to reserve rides and other traveller services. This category has four specific user services: Traveller Information; Route Guidance and Navigation; Ride Matching and Reservation; and Traveller Services and Reservations. DRIVES™ provides travellers with information prior to their departure to assist them in making mode choices, travel time estimates, and route decisions based on route planning and congestion information. Maps, using colors to indicate route speeds, showing the result of this system are illustrated in Figures 1a and 1b.

[0007] Though systems such as DRIVES™ provide information on traffic conditions, they receive their information from traffic sensor networks that are owned by governments, both local and provincial. To provide more accurate and detailed information to meet the interests and needs of drivers substantial expansion of government-owned traffic sensor networks would be required. However, this expansion is not feasible because many governments either simply do not have the resources to significantly expand their road sensor networks, or have other priorities on which to spend their limited funds.

[0008] Many drivers have expressed a desire to have advance notification of any impairment to their movement around the city, thereby allowing them to choose a route that will be more efficient at a specific time of day. These users are interested in the current speed of traffic along major routes, any congestion due to traffic volume, accidents or planned outages that might impair progress, weather conditions etc. Traffic congestion in our major cities will undoubtedly get worse, and there is strong interest by users in receiving more detailed real-time traffic information. In a U.S. survey conducted by Driscoll-Wolfe, 28% of respondents making 1 or more cell-phone calls per month said they would be willing to pay a fee for a location-based traffic information service. The results of this survey, indicating the likelihood of paying a monthly fee for location based traffic services for the total survey population, and several key demographic breakdowns is provided in Figure 2.

[0009] One solution is to find a technology that will allow traffic information to be gathered. Attempts have been made to use cellular phones as traffic probes using various techniques such as triangulating the location of a phone based on the Time Difference of Arrival (TDOA) and/or received signal strength at a variety of cellular sites. These methods are relatively inaccurate. Triangulation based on signal strength, for example, is an

inaccurate measure of location, as the strength of a digital cellular signal is typically reduced at its source so that it arrives at a nearby cellular tower with the same strength as any other signal. The intentional reduction in signal strength often makes the use of different cellular site readings difficult as the cellular sites further from the handset receive very faint signals. As a result, the triangulation of a cellular phone cannot resolve a location with sufficient accuracy to be able to determine which side of a highway a cellular phone is on. In other instances, a system cannot differentiate between a cellular phone on a service road adjacent a highway and a cellular phone on the highway. As a result cellular triangulation is considered to be too inaccurate for use as a traffic probe. The use of the timing differential between the receipt of the signal at different cellular sites is equally ineffective as a triangulation data source. These network-based approaches are relatively expensive because they require additional hardware and/or software at cell-tower sites and other nodes in the cellular network.

[0010] The provision of accurate, relevant and timely road conditions information has long been recognised as of value to travellers and traffic system management personnel. Currently, the state of practice with respect to the provision of traffic information is rather limited. Congestion information is provided at a very small number of fixed points along selected major freeways (i.e. variable message signs, known as VMS) and qualitative information is provided periodically over AM and FM radio and some local TV stations. While these methods of disseminating traffic information are of some value, they are significantly limited in terms of spatial coverage, accuracy, and timeliness of delivery to the traveller.

[0011] The most significant hurdle preventing the development and deployment of more robust and capable traveller information systems is the difficulty in obtaining traffic condition data. Infrastructure based traffic surveillance systems, such as in-road loop detectors, video imaging systems, and transponder based systems (i.e. Hwy 407 in Ontario), are very expensive to deploy and maintain over a large network. Furthermore, jurisdictional issues associated with private sector firms installing traffic surveillance equipment on public roadways and access to the right-of-way makes this approach particularly difficult.

[0012] Several attempts have been made to use cellular technology to deploy a large number of traffic probes.

[0013] Cell-Loc, of Calgary AB CANADA, has developed a system for measuring traffic speeds using Time Difference of Arrival (TDOA). This TDOA approach is not being implemented by the wireless carriers.

[0014] Applied Generics of Scotland has also developed a solution using a particular attribute of the GSM-based system whereby the signal strength from a number of adjacent cell towers can provide a rough order of magnitude positioning. Using this capability and a proprietary map-matching technique, the Applied Generics system can get a positional fix on a vehicle. Used in an iterative fashion, this technique can position a vehicle on known roads, however it is a computation intensive technique, as to determine the location of the probe a number of triangulation calculations must be made. There is a steep tradeoff between accuracy and computational complexity, which typically results in either inaccurate but quickly obtained result, and highly accurate but very computationally expensive results. As a result of the high degree of computational complexity involved in obtaining accurate position data this system will likely encounter scalability issues.

[0015] Decell Technologies Ltd. in Israel provides a service using technology based solely on the existing mobile network infrastructure. Decell enables mobile network operators to deliver personalized real-time route guidance to driving mobile subscribers. Their technology uses existing cell towers along major routes and uses the GSM capability of relative signal strengths to determine a user's position between towers. The service then uses traditional cell phone delivery mechanisms to provide traffic status information about the driver's route. Once again, the implementation of this system requires a number of highly complex calculations based on a plurality of tower strengths, and encounters scalability issues for large numbers of probes. Furthermore, the system does not extend to people other than the subscribers to a single carrier. The availability of multiple carriers increases the potential pool of probes, and ensures that in markets that are geographically divided between carriers that the information can be portable and accessible.

[0016] U.S. Department of Transportation (USDOT) and the Virginia Department of Transportation (USDOT) funded a feasibility test of deriving traveler information from cell phone usage. The technology under development by AirSage, Inc. of Marietta, GA attempts to derive travel time information on a wide variety of roadways, including both freeways and major arterial roadways. The goal of the systems test was to determine the viability of

providing real-time, area-wide traffic information through cellular-based traffic probes. The final evaluation report for the project concluded that "it appears that the costs of the cellular based system can be competitive with other technologies," however the project did not produce as results as accurate as hoped due to several factors, including problems with triangulation based geolocation accuracy. AirSage's technology requires the installation of two different software packages. One piece resides on the carrier's system and taps into all data on the network -- including potentially the identification and location of individual callers. That module then extracts data from the cellular company's network in a "non-intrusive" manner, strips out the identity of individual callers, and then communicates "movement records" back to AirSage. The second software piece, which is resident at AirSage, aggregates data from multiple cell phone carriers and then does geospacial analysis and mapping, and merges GIS data as well as the carriers' operational data.

**[0017]** SFR, ASF and INRETS have teamed under a $1 Million dollar (US) European project funded 50% by SERTI and managed by the French DoT. The team's objective is to locate and measure speed and direction of cars carrying wireless devices (cell phones) in order to provide road traffic operators with velocity and direction of travel on all roadways within any given service area. The project examines only network-based positioning.

**[0018]** Within the ITS Orange Book on Predictive Travel Time, there is a clear recognition that travel predictions and forecasts rest on the ability to also capture the current travel conditions. It identifies several related major programs and projects:

- The Intelligent Vehicle Initiative, which could lead to systems for data to aid PTT and/or provide dissemination methods.
- Transport Direct, a U.K. initiative, aims to provide the traveller with all the information required before and during a trip.
- The U.S. FHWA's Traffic Estimation and Prediction Software (TREPS) program is applying the concept of dynamic traffic assignment to traffic management and may also yield advancements for PTT.
- The "IP Car" (where IP stands for Intelligent Probe). The goal of this Japanese project is to facilitate advances in logistics and improvements in traffic management.

- Vehicle Relayed Dynamic Information (VERDI) was a floating car system implemented jointly by telematics service providers. VERDI uses GPS receivers in cars linked to a control centre via a GSM network.
- The Welsh Assembly Government has investigated floating car data, but felt there was an insufficient fleet of floating vehicles in Wales for this approach to be viable. Wales is now moving towards a hybrid system using loops and licence plate recognition systems.
- The Scottish Executive has signed a five-year contract for the supply of a journey time and traffic delay service on Scotland's roads. This uses information on the road system and historical data on delays that are regularly experienced.
- TravInfo in the Bay area uses a combination of the FasTrack AVI transponder system and loop detectors.
- Westwood One/SmartRoute Systems has a local traffic and weather information service that uses traffic data collected by 2,000 reporters, 65 fixed wing aircraft, 35 helicopters, and thousands of traffic cameras.
- Mobility Technologies has a "Traffic Pulse Network" that uses RTMS sensors.
- TrafficCast is a wholesaler of traffic and travel time information using a database of historical travel times linked to real-time highway conditions.

[0019] There is a great interest in predicting travel times and there are many ways to measure traffic speeds. As discussed above, there are five known projects that use cell-phones as traffic probes, but they all use network-based technologies, which are relatively inaccurate, expensive to deploy, and difficult to scale.

[0020] It is, therefore, desirable to provide a method and system of monitoring and managing traffic flow and congestion that is scalable and can take advantage of an easy to deploy traffic probe.

## SUMMARY OF THE INVENTION

[0021] It is an object of the present invention to obviate or mitigate at least one disadvantage of previous .

[0022] Another object of the present invention is to provide a system using cell-phones equipped with Assisted Global Positioning System (AGPS) chipsets as traffic probes to measure the speed of traffic.

[0023] In a first aspect, the present invention provides a system for monitoring traffic flow. The system includes a location based services interface, a filter, a traffic flow engine and an interface. The location based services interface receives, from a cellular network, location based information for at least one assisted GPS enabled cellular phone traffic probe. The filter filters the received location based information to remove aberrant location information, and for maps the received location based information to a position on a monitored road. The traffic flow engine, determines traffic flow based on the filtered location based information. The interface receives the determined traffic flow from the traffic flow engine and displays the determined traffic flow to permit monitoring. In an embodiment of the first aspect of the present invention, the filter includes means for mapping the received location based information to a position monitored road using a minimized missed distance algorithm.

[0024] In a second aspect of the present invention, there is provided a method of monitoring traffic flow. The method includes the steps of receiving location information corresponding to the location of at least one assisted GPS enabled cellular phone; filtering the received location information to remove aberrant location information and to map the received location information to a position on a monitored road; determining a traffic flow based on the filtered location based information; and displaying the determined traffic flow to permit monitoring.

[0025] Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Embodiments of the present invention will now be described, by way of example only, with reference to the attached Figures, wherein:

Figures 1a and 1 b are illustrations of traffic maps generated by a prior art system;

Figure 2 is a graph presenting survey results indicating the need for real time traffic information;

Figure 3 is a block diagram illustrating the architecture of a system of the present invention;

Figure 4 is a block diagram illustrating the connectivity architecture of a system of the present invention;

Figure 5 is a traffic flow map generated by a system of the present invention;

Figure 6 is a traffic flow map generated by a system of the present invention;

Figure 7 is a scatter plot indicating the positional accuracy of AGPS probes;

Figure 8 is a scatter plot showing the relationship between speed measurements of the system and reference speed measurements;

Figure 9 is a graph showing the variation of speed between the system measured speed and the reference speed measurements; and

Figure 10 is a traffic flow map generated by a system of the present invention.

**DETAILED DESCRIPTION**

**[0027]** Generally, the present invention provides a method and system for monitoring and managing traffic flow and congestion. The present invention leverages technology that allows traffic information to be gathered. Although alternatives exist and Globis has examined a range of options for generating additional traffic. In one embodiment, cell-phones are used as traffic probes to take advantage of the large number in use. This results in a low cost approach because it leverages the existing wireless infrastructure, and it is easily scalable and transportable to any market.

**[0028]** In the following discussion, acronyms will be used according to the following meanings.

| | |
|---|---|
| AGPS | Assisted GPS |
| ATLANTIC | A Thematic Long-term Approach to Networking for the Telematics and ITS Community |
| E-911 | Enhanced 911 |
| DAB | Digital Audio Broadcasting |
| GPS | Global Positioning System |
| IVR | Interactive Voice Response |
| LBS | Location Based Services |

| | |
|---|---|
| LIF | Location Interoperability Forum |
| MLP | Mobile Location Protocol |
| NRCAN | Natural Resources Canada |
| PTT | Predictive Travel Time |
| SMS | Short Message Service |
| VPN | Virtual Private Network |
| XML | Extensible Markup Language |

[0029] To provide traffic flow mapping, a technology that will allow traffic information to be gathered must be employed. Typically, systems have been employed using fixed probes such as loops and microwave stations. Floating probes such as dedicated GPS devices, taxi dispatch systems, bus fleet monitoring systems, Highway 407 transponder tags, 802.11b devices can also be used. AGPS enabled cell-phones are used in the presently preferred embodiment of the invention. The AGPS enabled cell-phones are presently preferred because:

- there are a large number in use, one Canadian cellular network has an estimated 1.3 Million customers using GPS-enabled cell phones
- it is a low cost approach because it leverages the existing wireless infrastructure
- as probes, they are easily scalable and transportable to any market

[0030] The enabling technology for this is based on the trend (and a legal requirement in some jurisdictions) that wireless carriers be able to determine the location of callers to 911; this capability is often referred to as Enhanced 911 or E-911. In addition, wireless carriers have seen the potential of this technology in a commercial environment and are in the process of deploying location-based services (LBS).

[0031] An initial testing program has been performed and included of a series of tests with various numbers of cell phones being driven around a test route under different traffic conditions. Drivers and observers reported the observed traffic speed and made odometer and time reports that subsequently provided a calculated speed. The observed speeds and the calculated speeds were then compared to the map color for each segment. The comparison was made with a 1 minute delay to account for latency in the system.

In the test, 14 cell-phones were deployed in a small geographic area in the west end of Ottawa and part of Gatineau, Quebec. This deployment demonstrated the ability of the system to accurately determine the position of cell-phones via the wireless carrier's network. From the position data, traffic speed information and traffic conditions were derived and could be displayed on a real-time map. In the testing, a basic set of algorithms was employed with the expectation that the project would help define the more sophisticated algorithms that would be needed in a commercial implementation.

Within the system developed for the project, the system's LBS interface "pinged" the cellular network's Location Based Services (LBS) server to obtain cell-phone position information. Based on the reported position, the cell-phone probe was geofenced to the specific routes of interest. The geofenced position is then compared to a previous position, and the delta between the two positions over the defined time interval is converted into a traffic speed vector, and displayed on a traffic map.

[0032] In the test, the cell phones appeared on the map in their expected positions according to driver reports. Also, the cell phones populated the map reliably.

[0033] An additional testing program measured the accuracy of the prototype system in three ways:

- The positional accuracy of the data from the LBS platform, i.e., the Latitude and Longitude data.
- The accuracy of the raw speed data from the software.
- The accuracy of the system's real-time traffic map on highways.

[0034] The results show that each component of the system was verified in the testing: the accuracy of the location data from cellular network, the calculation of traffic speed, and the transfer of this information to a map in three color codes.

[0035] The additional testing on an extended highway segment was very successful. The analysis of the results of the initial testing identified a number of changes to the initial algorithms and the need for rigorous observation. Observations and calculations were made consistently and accurately in order to complete testing successfully.

[0036] The testing confirmed that additional sophistication is preferable for monitoring traffic flow on arterial roads. For example, a car that is stopped, due to a traffic light, can be identified as being stopped at a traffic light and handled differently than a car that is stopped

because of an accident. Alternatively, the system can average these results with the previous and subsequent stop light conditions to calculate an average speed, based on the rationale that the red light time at an intersection is part of the normal flow of traffic on the arterial.

[0037] The present invention leverages the capability to accurately determine the position of modern cell phones working with modern cellular networks. Many cell-phones currently sold have a built-in Global Positioning System (GPS) chipset that can, when augmented by the cellular network, determine the position of the cell phones to a relatively high degree of accuracy. As the position information is not solely derived from a set of difficult to manage data points, the calculations are less computationally complex, and are more scalable to a system with a larger number of probes to provide finer granularity in the data.

[0038] Figure 3 illustrates an architecture for a system of the present invention. Each element in the system is preferably designed to be a stand-alone element in the system to allow for redundancy and re-use of existing components in the network. There is no preference or limitations in how code is written or the language in which it is coded other than a preference that a high quality index was to be maintained, and that adequate management techniques are incorporated to allow for code maintainability and adjustments to certain parameters as needed.

[0039] The system architecture can be designed as an extension of existing traffic flow monitoring systems already in effect, such as the current D.R.I.V.E.S. services in Toronto and Montreal. The use of the existing architecture allows for the reuse of the current system modules, and can provide a savings for both time and money.

[0040] Each module is preferably designed to be as close to stand-alone as possible for maximum flexibility. Among other benefits, this allows for evaluation of each module's operation and characteristics before passing the processed data to the next stage. Additionally, enhancements can be made to a single module without the surrounding modules requiring any change in their design or operation.

[0041] Figure 4 illustrates the hardware connectivity utilised in an embodiment of the present invention. As illustrated in Figure 4, a computer, indicated as D.R.I.V.E.S. Ottawa, hosts a series of application, and connects to a location based services server (LBS), which resides in a cellular network, indicated as Bell Mobility. The connection preferably includes a

pair of Virtual Private Network (VPN) routers providing security for the flow of data traffic between the computer and the cellular company's network from other traffic on the data network connecting them, illustrated as Internet. The use of a physical private network between the cellular network system and the host computer would allow for the removal of the VPN routers; the implementation of the system as a part of the cellular company's network, or securely connected to the cellular network, would also reduce the need for additional network security.

[0042] With reference again to Figure 3, Application 1 preferably requests and retrieves the cell-phone AGPS data on a flexible schedule and places the results in a datafile that can be accessed and archived. Access to cellular network LBS systems is typically tightly controlled.

[0043] The access protocol preferably used is the Mobile Location Protocol (MLP) version 1.2 developed by the Location Interoperability Forum (LIF). LIF's MLP is XML based and is preferably carried through a Virtual Private Network (VPN) secure link between a the host computer and the LBS platform, both illustrated in Figure 4. The following table describes the functionality of this application module:

| INPUT | OUTPUT |
|---|---|
| Probe ID's | Location request (XML) |
| Pinging frequency | Create AGPS log entries |
| Accuracy requirement | LBS Error messages |
| VPN access ID / password | LBS Location response (XML) |
| Location response (XML) | |

[0044] Application 2 is preferably used to access the location data from the AGPS log created by Application 1, and applies appropriate algorithms to verify the usefulness of the data for further processing. The data is then converted into a standard structure for further processing.

[0045] Application 2 applies georeferencing to the data and develops the probe location data file while at the same time developing the average speed for the segment of road based on predetermined instructions. The development of IVR data while not a prime intent of this trial is a logical derivative of this application module.

[0046] The algorithms preferably select (or discard) data that is outside a predetermined set of criteria and identify the road segment the data applies to. The AGPS positional information uses the regular constellation of GPS satellites. However, cell-phones are not always in optimal locations to be able to see the necessary numbers of satellites to provide the best possible resolution. The data is therefore supplemented by positional data obtained from triangulation based on the cell-phones' strongest signal. The result is that there is an uncertainty of position. This uncertainty is used in two ways:

- First, location data with a radius of uncertainty greater than a predefined threshold is preferably filtered out and not used. This threshold can be adjusted during calibration trials when only a limited number of cell-phones were being used, and can be later adjusted as the number of probes increases to select only probes with a small radius of uncertainty. A balance can be achieved between the data points to be included and those to be discarded due to their creating erroneous readings on the speed calculations.
- The second part of the algorithms deal with allocating data points to the correct road segments. The selected method uses a classical orthogonal approach whereby the location of a probe is allocated to a road segment and a place on the segment that is closest to the cell-phone probe. The vector from the cell-phone to the closest road segment and the road segment itself meet at a right angle, which serves to minimize the missed distance between the probe and the road. In cases where the missed distance between a probe and a road results in an ambiguity (e.g. two road segments intersect, and the probe is an equal distance from both segments) then other algorithms can be used to resolve this ambiguity through the analysis of the previous data.

[0047] The following table describes the functionality of this application module:

| INPUT | OUTPUT |
|---|---|
| AGPS data from each probe | Speed log datafile |
| Accuracy requirement | Location log datafile |
| Required algorithms | Data file in XML format for IVR |

| | |
|---|---|
| | delivery |
| Road segment definitions | Updates the cell-phone location database |
| Posted speed definitions | |
| Colour/speed definitions | |

[0048] Application # 4, is preferably used to upload various files to the web site at fixed intervals (e.g. at minute intervals). Some of these files are used by the web site itself, and an XML file is downloaded to the IVR engine. This allows for the updating of mapping applications, and provides the IVR system with updated information to provide to users.

[0049] In implementation numerous settings in the application modules can be modified to provide improved performance. The uncertainty thresholds applied by application #2, if set too strictly, can result in the discarding of excessive amounts of data, which results in an insufficient number of useable probes. In operation the system is preferably tuned to account for acceptable uncertainty to balance both obtaining accurate information, and accessing a sufficient number of probes.

[0050] Commonly observed routes include both highways and arterial roads, some of which have traffic lights. When a car stops at a traffic signal, the resulting velocity vectors are indeterminate, and the system can become "confused" as to which direction the car is travelling in. In conjunction with the uncertainty of the car position, the system may have a tendancy to paint the traffic zone red, stopped, in both directions. This problem can be addressed by using a historical record showing the past direction for each vehicle. It can be assumed that a vehicle that was travelling in a given direction, such as east, if it stops, will continue travelling east. Its direction can be monitored, and it will not be counted as a vehicle in the westbound lanes, unless a predetermined number of samples show it as having a westbound direction. This allows vehicles to turn around and still be counted, but stops eastbound probes from stopping and being seen as in the westbound lanes.

[0051] As roads are preferably divided into segments or zones, so that each segment can show a different traffic flow, it is possible that some zone boundaries were close enough to each other that it was possible for a vehicle moving at the posted speed to traverse a zone without getting pinged. A zone extrapolation utilizing a set of algorithms can be employed to

colour the zone based on adjacent zone colours, thereby compensating for the missing data. As the number of probes in a system is increased, the probably of this result diminishes.

**[0052]** Tests of the system included both highway and arterial traffic monitoring. Stop-lights on arterial roads generate red zones on the map because sequential pings indicate that the vehicle is stopped. While this is correct in one sense because the vehicle is actually stopped, it may not indicate that traffic flow is red. The stopped vehicles are part of the normal flow of traffic on arterial roads. An averaging process over a few minutes can be employed to reduce the number of red zones attributable to stop lights if so desired.

**[0053]** Pinging cell phones for location information, while they are entering or leaving a limited access highway can also result in false red or yellow results, due to inherent slowdowns associated with slower traffic coming up to highway speeds and merging with highway traffic. As the number of probes in the system is increased the existing algorithms will eliminate these results by averaging the merging traffic results with the traffic results of probes already travelling on the highway.

**[0054]** Observation and calculation errors may result in yellow zones being calculated as green, but an as the number of probes in the system increases, the overall traffic patterns will allow for a more accurate representation of the traffic flow conditions.

**[0055]** In testing, highway results were isolated and analyzed separately. Generally the results are slightly better than the overall results but the same pattern of errors as identified above remained. A review of the results shows that some of the calculated result errors are attributable to the averaging of speed results from the arterial roads at the highway exit points. For example, incorrect red map segments may be attributable to vehicles being stopped for a red light just before the entrance to a highway. As indicated above, as the system is fully deployed with a greater number of probes, the averaging of the results will reduce the effect of such a situation.

**[0056]** Figures 5 and 6 illustrate the mapping of the location results from an embodiment of the system of the present invention.

**[0057]** In use, the system of the present invention consistently paints a map green, yellow, and red even when a small number of cell phones are being pinged. The results are based on a combination of observations calculations and results on both arterial roads and a highway segment. Due to the limited number of probes the results on arterial roads may

have inaccuracies due to the over-reporting of red results and possible observation bias to report after acceleration to normal speed.

**[0058]** To calibrate the AGPS results for the system a known station marker can be used, and the AGPS results of several probes, preferably representing each cellular carrier used, can be calibrated against the position. This will give an uncertainty value for each carrier network, and possibly for each phone type. The calibration can also be done using a number of known station markers, and a drifting positional uncertainty can be used. For the testing, a Natural Resources Canada (NRCAN) station marker was selected; it had easy access and its position was known to within ±1 millimetre in both a northing and easting position. Four phones were set up directly on top of the marker and 250 data points were collected. The resulting positions (Latitude and Longitude) were logged by the software and the results were subjected to further analysis. Using known spherical geometry calculations, the apparent distances between the cell-phones and the reference station marker were calculated.

**[0059]** It should be noted that the horizontal datum used for the reference position used the NAD83CSRS standard, whereas the reference used for the AGPS positions is the WAC84 standard. A comparison of these two standards showed that the introduced error is zero meters for the Longitudinal positions, and less than 0.0001 meters (at a Latitude of 45 degrees) for the Latitudinal. This level of error is considered to be acceptable for the purposes of conventional traffic flow monitoring.

**[0060]** As can be seen from the Figure 7, the average inaccuracy was approximately 7 meters and over 99% of the results had an accuracy better than 20 meters. The consistent accuracy of better than 20 meters is very acceptable for using cell-phones as traffic probes. It should mean that adjacent roads not closer than approximately 30 meters apart can readily be discriminated and therefore presented in a graphical mapping format.

**[0061]** To determine the accuracy of the "raw" speed data from the software testing against known results can be performed. The "raw" speed is defined as the actual speed in Km/hr as determined by the software and prior to the application of algorithms. (The algorithms determine whether the vehicle is on a highway/road of interest, which zone it is in, and the zone colour based on all vehicles in the zone at that time.) The approach to this part of the testing was as follows:

- Calibrate the speedometers on the two cars used for this test, based on the time to travel a route measuring exactly 4.55 Km. A speedometer adjustment formula was developed for each vehicle and this formula was applied to all speedometer readings.
- Drive along a highway at a constant speed and record:
    - The precise time as displayed on the D.R.I.V.E.S. Ottawa server,
    - The car's speedometer reading, and
    - The speed as determined by the software (this speed was automatically logged by the software with a date and time stamp).
- Repeat the second step for various speeds.

**[0062]** Figure 8 illustrates a scatter plot of 51 data points obtained using the testing outlined above. These were used as source data for a scatter diagram that shows the relationship between the two sources for the speed data.

**[0063]** Note that the parameter "Km/hr from Speedometer" incorporates the adjustment factor resulting from the speedometer calibrations. To further investigate the variation between the two sources of speed data, a second scatter diagram was developed showing the percentage variation at various speeds.

**[0064]** Figure 9 illustrates the following:

- The average of all errors across all speeds is consistently less than 1%.
- The range of data points at just over 100 Km/hr is from +3.2% to – 3.0% relative to the corrected speedometer readings.
- The range of data points 45 Km/hr is from +7.4% to –10.5% relative to the corrected speedometer readings.

**[0065]** The above described accuracy is sufficient for determining the speed of traffic, especially when the algorithms incorporate an averaging function. Figure 9 also shows that at lower speeds, the spread between the data points increases. This raises an important question: why is the system less accurate at lower speeds? The answer lies in some simple mathematics:

- At 45 Km/hr, as mentioned above, the calculated speeds range from +7.4% to –10.5% relative to the corrected speedometer reading.

- At 45 Km/hr, a car travels 375 metres every 30 seconds (the interval used for pinging the LBS).
- The positional accuracy tests described above show that the worst case positional error for over 99% of the data points is 20 metres (although the mean error was 7 metres).
- In a true worse case situation in which a pair of pings are worst case in opposite directions, the maximum error in the distance travelled would be 40 metres.
- The worst case percentage error in distance travelled is therefore 40 x 100/375, i.e. 10.7%.
- This means that in the same worst case situation, the calculated speed would also be out by 10.7%. This theoretical value is very close to 10.5%, the worst measured error at 45 Km/hr.

**[0066]** As a result, at lower speeds, the distance travelled between pings is less and the impact of the positional inaccuracy is greater. Increasing the time between pings would, of course, increase the distance travelled and reduce this effect, but there are trade-offs with other factors. The addition of additional probes into the system will offset the averaging errors.

**[0067]** The testing of the system, with only a small number of traffic probes indicates that the average of the errors at all speeds is consistently less than 1%, and that the range of the error in the data points varies from +3.2% to – 3.0% at just over 100 Km/hr, to +7.4% to – 10.5% at 45 Km/hr. This range of errors is sufficiently accurate enough for determining the speed of traffic.

**[0068]** An extended portion of a Highway was defined for a highway-only test. The zones for this test were set to be somewhat larger than the zones for the previous test to allow for more pings to the same cell phone probe while within a single zone. Reporting points for observation and odometer readings were predefined to ensure more consistent measurement and small observation intervals eliminated to reduce the potential impact of small distance errors creating large speed calculation errors. The first test consisted largely of normal traffic with a few reductions of speed. The second test was held in peak time with more yellow and red reported.

[0069] Results for this test yielded only 1 yellow result that was user observed as green. The results are actually better than they appear. The map colour changed consistently approximately 40 seconds after a report of an observed traffic speed change. Especially at slower speeds, this sometimes resulted in changes in the map colour while the test vehicle was in the zone. This was reported by observation. The one yellow result observed as green also had a brief period of time as yellow. There were a number of other occasions where the map briefly changed a zone from green to yellow and then back. This was also confirmed by observation. The results of the above described highway test are presented in Figure 10.

[0070] The tests confirm that the system performed to near 100% accuracy, with the exception of the single no data zone. The observation of 40 second latency was significantly better than had been anticipated. The system accurately reflected changes in speed while the vehicle was within a specific zone, and successfully describes the speed of traffic on highways.

[0071] Testing also suggests that the logic used for mapping the flow of arterial roads should be more sophisticated than the logic implemented currently for highways. The enhanced logic should handle vehicles as stopped at a traffic light according to operator preference, so that they can either be averaged over time, or show as stopped.

[0072] The system of the present invention can be used in a number of environments at a reasonable cost. In addition to arterial roads and highways, the system can be applied to border crossings and bridges, so that traffic flow can be monitored and managed. The system can be implemented by a number of entities, and may be marketed to distinct markets including government transportation agencies, individual drivers (commuters, professionals, etc.), fleet operators, and traffic information providers.

[0073] The reporting of information can be done in a number of ways. Though described above with reference to mapping software, and an IVR interface, the generation of the location information can be leveraged over a number of interfaces. As described above, the location information is preferably stored as an XML file, that can then be accessed by any of a number of interfaces, including short message service (SMS) based interfaces, that can either interactively, or in a pre-programmed fashion, transmit updates to users via their cellular phones. IVR systems can provide traffic updates using either a DTMF or voice

recognition engine to allow for hands free operation. Direct Audio Broadcasting (DAB) transmissions can also be used to provide the information to users, as can email messages transmitted to internet accessible devices. The multiple distribution platforms allows for advertising revenues (primarily in conjunction with a world wide web based mapping interface), and fee for service models, including a periodic flat fee or a pay for use implementation.

**[0074]** The above-described embodiments of the present invention are intended to be examples only. Alterations, modifications and variations may be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

What is claimed is:

1. A system for monitoring traffic flow comprising:

a location based services interface for receiving, from a cellular network, location based information for at least one assisted GPS enabled cellular phone traffic probe;

a filter for filtering the received location based information to remove aberrant location information, and for mapping the received location based information to a position on a monitored road;

a traffic flow engine, for determining traffic flow based on the filtered location based information; and

an interface, for receiving the determined traffic flow from the traffic flow engine and for displaying the determined traffic flow to permit monitoring.

2. The system of claim 1, wherein the filter includes means for mapping the received location based information to a position monitored road using a minimized missed distance algorithm.

3. A method of monitoring traffic flow comprising:

receiving location information corresponding to the location of at least one assisted GPS enabled cellular phone;

filtering the received location information to remove aberrant location information and to map the received location information to a position on a monitored road;

determining a traffic flow based on the filtered location based information; and

displaying the determined traffic flow to permit monitoring.

## ABSTRACT

A system for traffic and congestion monitoring and management is disclosed herein, using GPS enabled cellular phones as traffic probes.

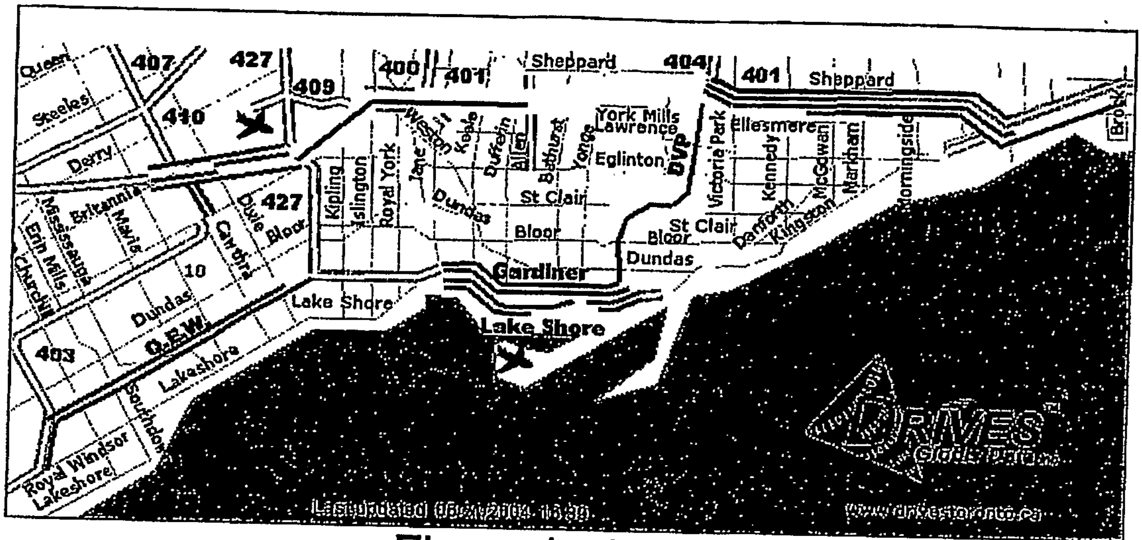


Figure 1a (prior art)

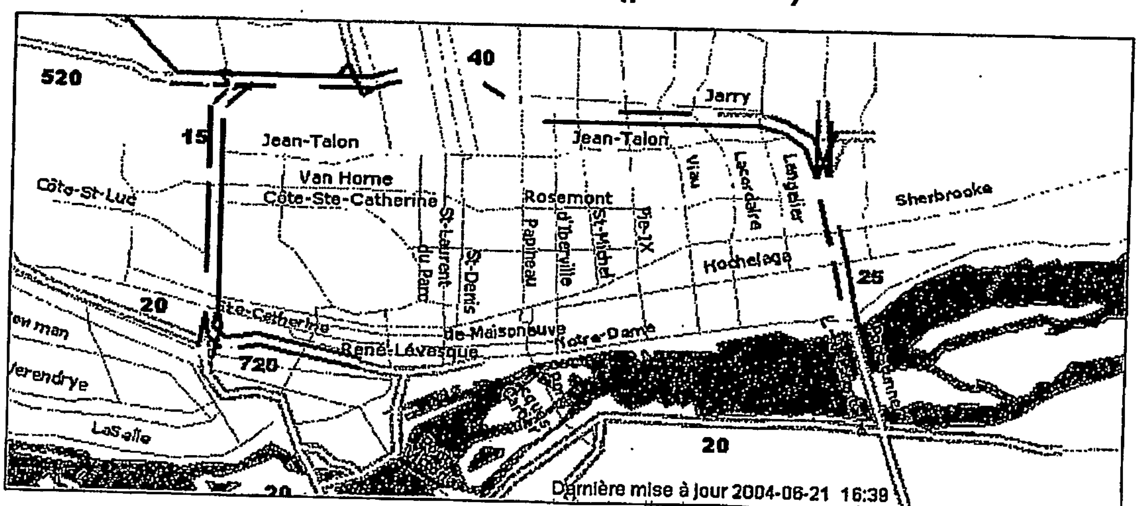


Figure 1b (prior art)

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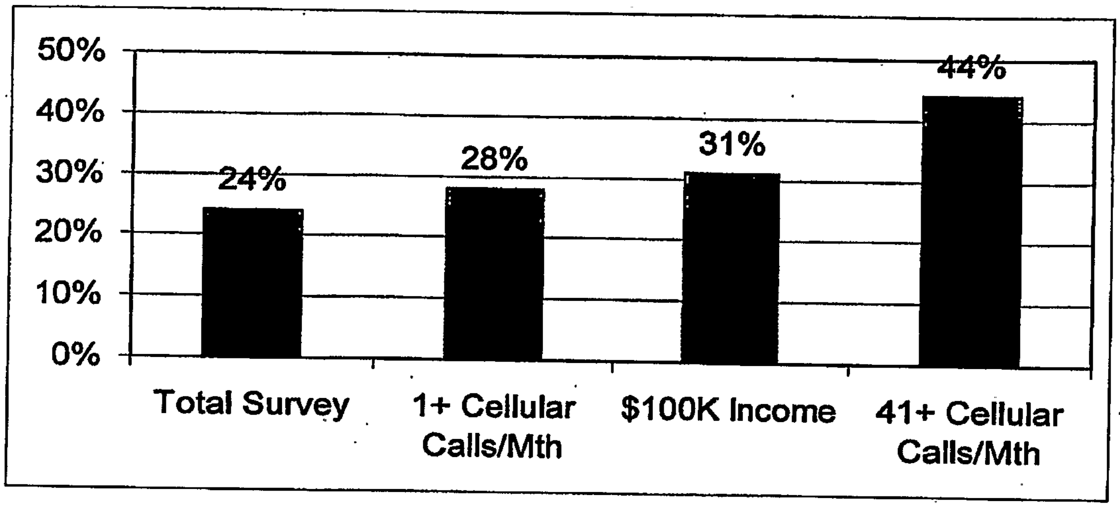


Figure 2

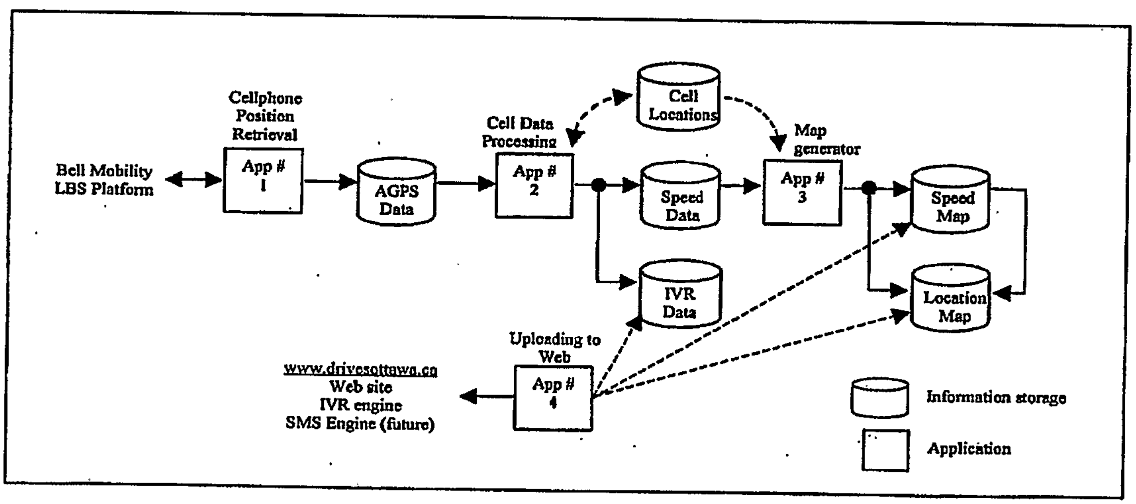


Figure 3

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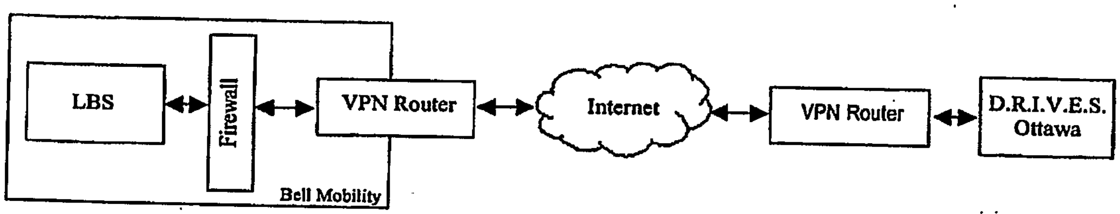


Figure 4

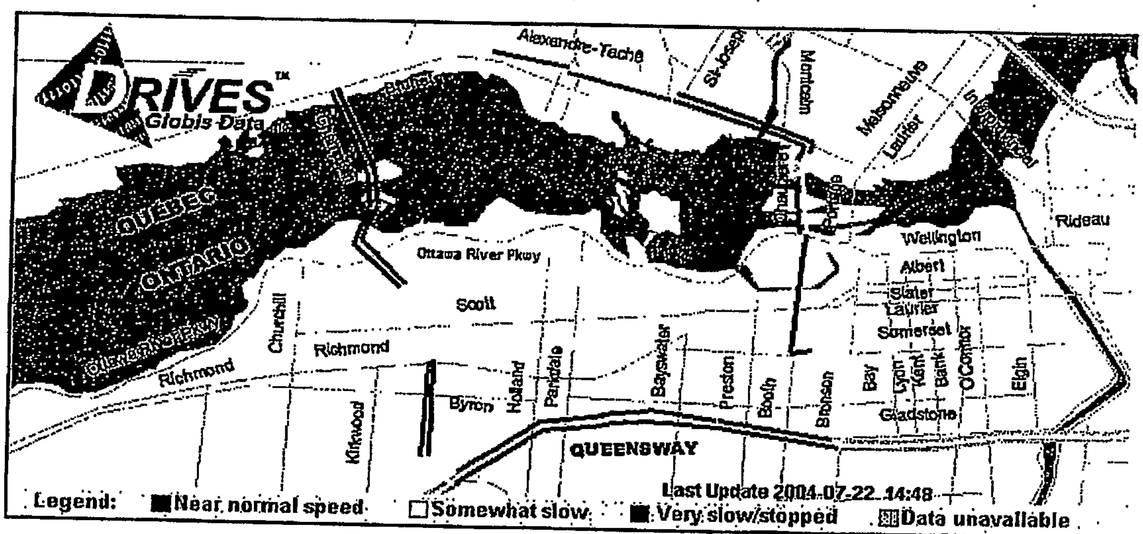


Figure 5

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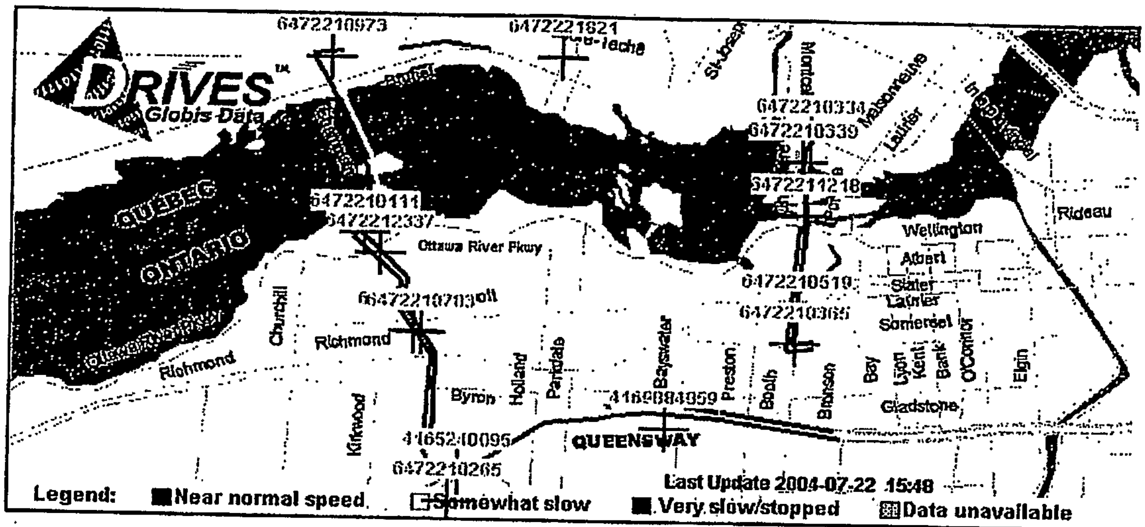


Figure 6

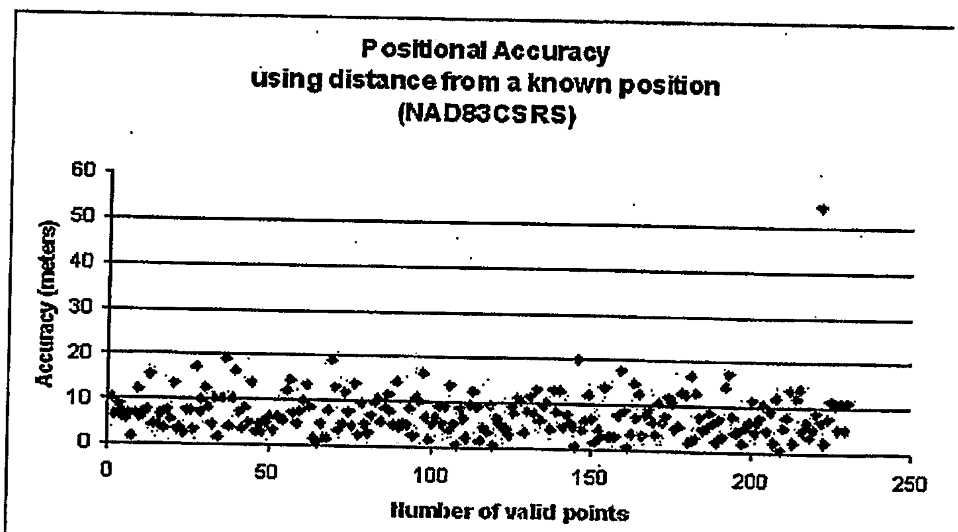


Figure 7

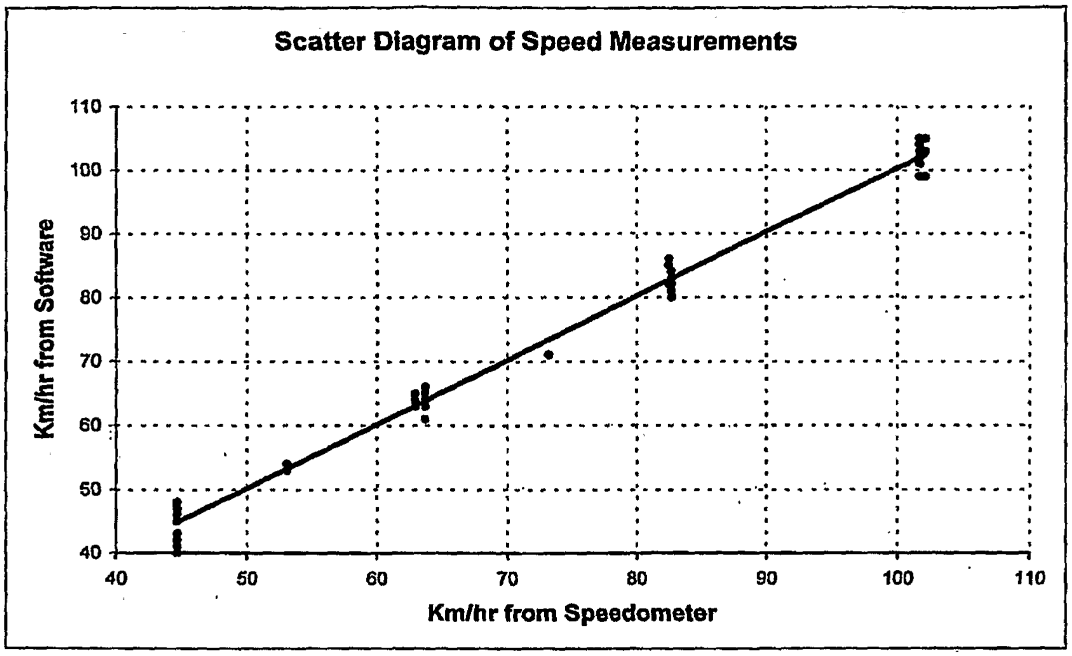


Figure 8

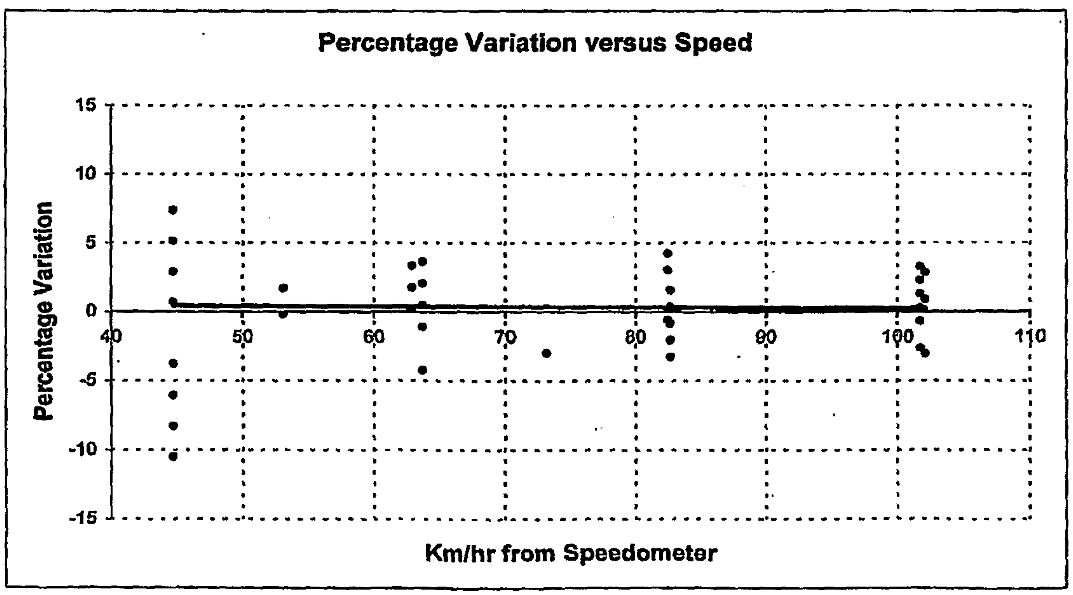


Figure 9

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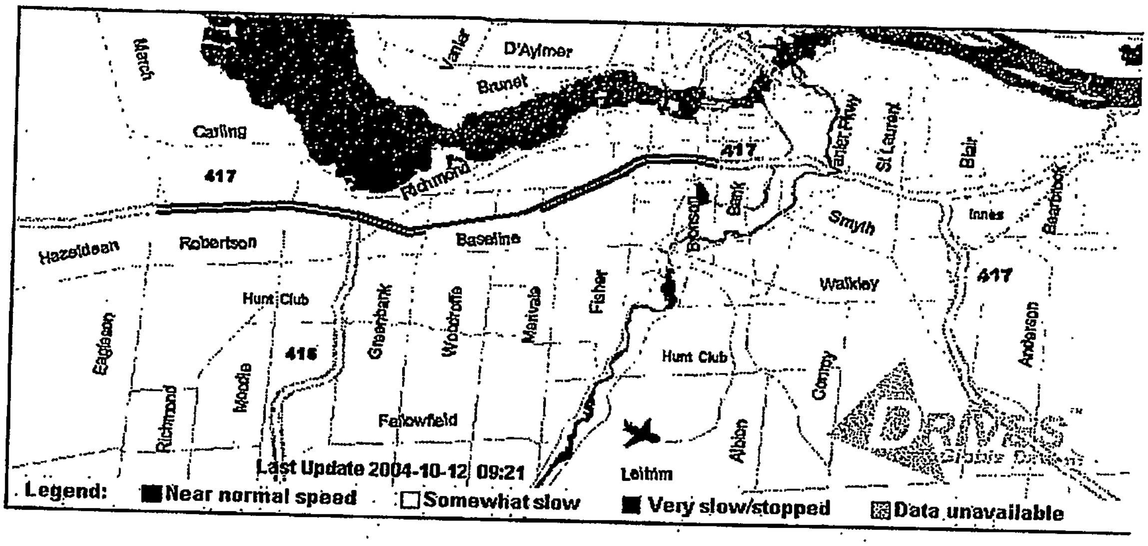
March
Vanier
D'Aylmer
Brunet
Carling
417
Richmond
417
St Laurent
Blair
Smyth
Innes
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Baseline
Bronson
Bank
Walkley
417
Hunt Club
Greenbank
Woodroffe
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Fisher
Eagleson
416
Hunt Club
Conroy
Anderson
Moodie
Richmond
Fallowfield
Albion
Leitrim
Last Update 2004-10-12 09:21
Legend: Near normal speed Somewhat slow Very slow/stopped Data unavailable

Figure 10